

Antacid Comparison Laboratory – Instructor’s Version

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Date of Experiment:

OBJECTIVES

- Students will perform a back-titration
- Students will learn the mechanism of various antacids
- Students will gain an understanding of gastric acid and basics of the digestive system

INTRODUCTION

This experiment is designed to model the effect of different antacids on gastric acid. Antacids, a class of medication typically bought over the counter, are drugs designed to combat harsh acidic environments in the stomach that are associated with ailments such as heart burn, indigestion, and upset stomach. Gastric acid is the solution in your stomach responsible for chemical digestion of foods. It typically has a pH of around 1.55 and is comprised of dilute hydrochloric acid, sodium chloride, and digestive enzymes.¹ When its pH falls too low or the mucus of the stomach lining wears too thin, complications typically arise where antacids are needed.

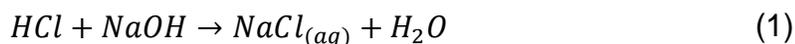
Since the purpose of this lab is to measure the amount of HCl neutralized from the addition of various antacids, it is not necessary to add the digestive enzymes to the solution. The concentration of HCl in simulated gastric acid is 0.08 M and the solution also contains 0.2% (w/v) NaCl. 6.0N HCl is 8.1% wt. HCl and the rest water.^{1,2} For the purposes of this lab, a dilute solution of hydrochloric acid is all that is needed.

The aim of this laboratory experiment is to quantify the amount of HCl neutralized by two different antacids. The active pharmaceutical ingredients (APIs) in antacids work by either raising the pH and/or by buffering the solution so it is resistant to further pH change. This lab will deal with antacids that work through



Figure 1. Antacids used in this experiment

the first mechanism. The amount of acid neutralized will be measured through a process known as back titration. This is done by adding a known volume and concentration of HCl to the antacid, allowing it to react, and then using a known concentration of NaOH to bring the solution back to a neutral solution. When the solution reaches a neutral pH the titration has reached its end point. The end point is found through the addition of an indicator to the solution that changes color when the solution reaches a certain pH. The amount of NaOH needed to completely neutralize the HCl is the amount of HCl that did not react with the acid. This is because the neutralization reaction that occurs involves a 1:1 stoichiometric ratio of HCl to NaOH, so the moles of NaOH added is equal to the amount of HCl left in solution. The reaction is:



The exact procedure for performing this titration is below.

MATERIALS NEEDED

- Safety gloves
- Lab goggles
- 2 Graduated cylinders
- Scale and weigh boats
- 300-500 mL beaker
- 50 mL burette
- Ring stand and clamp
- Funnel
- 1.0 M HCl
- 1M NaOH
- Phenolphthalein solution
- Dropper
- 1 green or yellow Tums[®] regular strength tablet
- 1 original formulation Alka-Seltzer[®] tablet
- Magnetic stir bar and hot plate
- Pestle and mortar

PROCEDURE

Make sure safety glasses and gloves are worn at all times in the lab!

1. Grind up 1 tablet with the pestle and mortar. Make sure the tablet is either green or yellow, because a tablet of any other color will make it hard to see the titration endpoint.
2. Place a weigh boat on the scale and tare the machine. Carefully transfer the powder from the mortar to the weigh boat and record the weight of the powder.
3. Using one of the graduated cylinders, carefully measure out 50 mL of 1.0 M HCl.
4. Add the powder to the beaker and pour the HCl into the beaker.

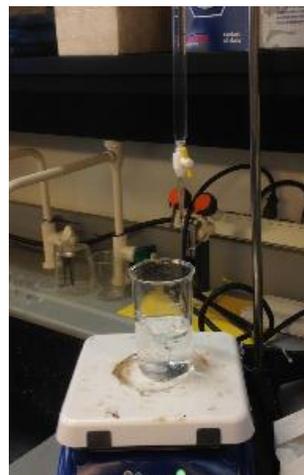


Figure 2. Titration setup

5. After the solution is done foaming, gently drop a stir bar into the beaker and place the beaker on the hotplate.
6. Heat and stir the solution on the lowest setting for three minutes to drive off any CO_2 still dissolved in solution. Do not let the solution boil.
7. Remove the beaker from the hotplate and allow the hotplate and beaker to cool.
8. Add five drops of phenolphthalein to the mixture.
9. Attach the burette to the ring stand using the clamp.
10. Place the beaker back on the stir plate and position the burette over the beaker.
11. Begin stirring the solution on the lowest setting.
12. Using a funnel, add 1.0M NaOH to the burette until it is filled to the 0 mL line.
13. Titrate the NaOH into the HCl. Look for a red streak starting to appear in solution, this means the mixture nearing the endpoint of the titration. At this point add the NaOH carefully.
14. Once the solution has completely turned red/pink, record the final volume of NaOH needed to neutralize the acid.
15. Empty the solution down the drain.
16. Repeat the procedure for one Alka-Seltzer[®] tablet.



Figure 3. Titration endpoint

QUESTIONS

- 1) Using stoichiometry, determine how many moles of acid each type of antacid neutralized. Then convert this to grams. Which antacid neutralized more acid? How do you know?
- 2) The mass of the Alka-Seltzer[®] and TUMS[®] are different. Which antacid had the most effectiveness per weight of the entire tablet?
- 3) Look up the prices of both drugs online or in the pharmacy. Which one is more cost efficient?
- 4) Why do you think the solution had to be heated to drive off the remaining CO_2 ?
- 5) How accurate of an indicator do you think the phenolphthalein was?
- 6) Based off of your answer above, how reliable are the results of this lab?
- 7) What is another way to measure the NaOH required to neutralize the remaining HCl?
- 8) The two antacids neutralize the hydrochloric acid using different reactions.

- a) What is the reaction that takes place when Tums[®] come in contact with gastric acid? What is the reaction when Alka-Seltzer[®] comes in contact with gastric acid?
- b) Which of these reactions most effectively neutralizes acid?
- c) Using the label on each package, estimate the number of moles of each of the active ingredients in the tablets. Based on this information, why do you think one antacid was more effective than the other?
- 9) The active ingredient in TUMS is Calcium Carbonate. Calcium Carbonate is a tasteless, white powder. Since TUMS are a chewable tablet, flavors are added to encourage people to take the medication. Two of the excipients listed on the TUMS[®] package are sodium polyphosphate and corn starch. Most of the others are colors and flavors which enhance the appearance and taste of the tablet.
- a) What is sodium polyphosphate? Why is it used in the TUMS[®]?
- b) Corn starch is frequently used as an excipient in pharmaceuticals. What properties of corn starch make it a good excipient?
- Be sure to cite your references.

ANSWER KEY

The following solutions are based off of empirical data below

Table 1. Sample data obtained through experimentation

Measurement/Calculation	Tums [®]	Alka-Seltzer [®]
Mass of tablet (g)	1.24	3.17
Concentration of HCl (M)	1	1
Volume of HCl (mL)	50	50
Concentration of NaOH (M)	1	1
Volume of NaOH (mL)	36.6	43.2
Difference in Volume (mL)	13.4	6.8
Moles HCl neutralized (mol)	1.34E-02	6.80E-03
Mass HCl neutralized (g)	4.89E-01	2.48E-01
Moles neutralized/weight (mol/g)	1.08E-02	2.15E-02
grams neutralized/gram of tablet	3.94E-01	7.82E-02

1. Using stoichiometry, determine how many moles of acid each type of antacid neutralized. Then convert this to grams. Which antacid neutralized more acid? How do you know?

ANS: The tums will neutralize more acid. We determine this from the table above, with the following equations. The sample calculations shown are for the TUMS[®] trial run.

$$\begin{aligned}
 \text{mol}_{\text{HCl}} &= \text{vol}_{\text{HCl}} * \text{conc}_{\text{HCl}} = 13.4 \text{ mL} * \frac{\text{L}}{1000 \text{ mL}} * \frac{1 \text{ mol}}{\text{L}} \\
 &= 1.34 * 10^{-2} \text{ mol} \\
 g_{\text{HCl}} &= \text{mol}_{\text{HCl}} * \text{molmass}_{\text{HCl}} = 1.34 * 10^{-2} \text{ mol} * \frac{36.46 \text{ g}}{\text{mol}} \\
 &= 4.89 * 10^{-1} \text{ g}
 \end{aligned}$$

$4.89 \times 10^{-1} \text{ g HCl neutralized} > 2.48 \times 10^{-1} \text{ g HCl neutralized}$

2. The mass of the Alka-Seltzer[®] and TUMS[®] are different. Which antacid had the most effectiveness per weight of the entire tablet?

ANS: The tums did. It neutralized more acid and weighed less.

Again, the sample calculations shown are for the TUMS[®] trial run.

$$g \text{ acid dissolved per tablet} = \frac{g_{\text{HCl}}}{g_{\text{tab}}} = \frac{4.89 * 10^{-1} \text{ g}}{1.240 \text{ g}} = 3.94 * 10^{-1}$$

$$3.94 \times 10^{-1} \frac{\text{g HCl neutralized}}{\text{g tablet}} > 7.82 \times 10^{-2} \frac{\text{g HCl neutralized}}{\text{g tablet}}$$

3. Look up the prices of both drugs online or in the pharmacy. Which one is more cost efficient?

ANS: This answer will vary depending on the source. When shopping online at www.cvs.com, a 150 count of Tums[®] Regular Strength Tablets currently costs \$5.49. A 24-tablet box of Alka-Seltzer[®] Original costs \$5.99.

Therefore, the tums costs \$0.04/tablet and the Alka-Seltzer costs \$0.25/tablet. The tums will almost always be significantly cheaper.

4. Why do you think the solution had to be heated to drive off the remaining CO₂?

ANS: Because this was an equilibrium-restricted reaction. The reaction is reversible, and carbonic acid will form if the CO₂ is not driven off by heating the solution. Gas is less soluble in hot solutions. If there is carbonic acid left in the solution, it will take more NaOH to titrate to a neutral pH, so the results of the experiment will be skewed.

5. How accurate of an indicator do you think the phenolphthalein was?

ANS: A quick internet search will return the answer.

Phenolphthalein is colorless in solutions where the pH is below 8.2, but pink to purple in solutions with a higher pH. A perfectly neutral solution has a pH of 7.0. Therefore, the solution will require slightly more NaOH to reach the titration endpoint than necessary to become perfectly neutral.

6. Based off of your answer above, how reliable are the results of this lab?

ANS: Since more NaOH is required than actually necessary to reach a pH of 7.0, the results of this lab are slightly inaccurate and

should only be used to *approximate* the difference in magnitude of HCl neutralization by the Tums[®] and Alka-Seltzer[®] tablets.

7. What is another way to measure the NaOH required to neutralize the remaining HCl?

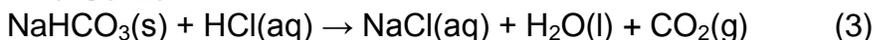
ANS: A more accurate method would be to use an electronic pH probe, and a less accurate method would be to constantly test the solution with litmus paper as NaOH is added.

8. The two antacids neutralize the hydrochloric acid using different reactions.
a. What is the reaction that takes place when Tums[®] come in contact with gastric acid? What is the reaction when Alka-Seltzer[®] comes in contact with gastric acid?

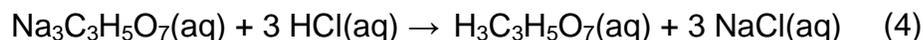
ANS: Tums[®]:



Alka-Seltzer[®]:



And



- b. Which of these reactions most effectively neutralizes acid?

ANS: The last reaction, equation 4, most effectively neutralizes the acid because 1 mole of Sodium citrate neutralizes 3 moles of hydrochloric acid.

- c. Using the label on each package, calculate the number of moles of each of the active ingredients expected to be in the tablets, then use stoichiometry to determine how many grams of hydrochloric acid should be theoretically neutralized. Based on this information, which of these antacids do you expect to be most effective? Is this consistent with the results you obtained from your experiment? Why do you think this is?

ANS: A sample calculation is shown.

$$1000 \text{ mg CaCO}_3 \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol}}{100.1 \text{ g}} \times \frac{2 \text{ mol HCl}}{1 \text{ mol CaCO}_3} \times \frac{36.45 \text{ g HCl}}{1 \text{ mol HCl}} \\ = 0.438 \text{ g HCl neutralized}$$

Table 2: Table of sample results for calculations involving the APIs in antacids.

Active Ingredient	Acid Neutralized
Citric Acid	0.569 g
Sodium Bicarbonate	0.831 g
Calcium Carbonate	0.438 g

Based on these results, you would expect that the Alka-Seltzer[®] would be more effective than TUMS[®]. This contradicts the results of the lab. This is due to the fact that the two reactions in the Alka-Seltzer[®] are competing with one another.

9. Two of the excipients listed on the TUMS[®] package are sodium polyphosphate and corn starch. Most of the others are colors and flavors which enhance the appearance and taste of the tablet.
- What is sodium polyphosphate acid? Why is it used in TUMS[®]?
ANS: Sodium polyphosphate is a class of compounds consisting of several linear chains of NaPO_3 chains, which are terminated by Na_2PO_4 groups. In TUMS[®], this excipient can be used as a sequestrant, which may be used to regulate acidity.³
 - Corn starch is frequently used as an excipient in pharmaceuticals. What properties of corn starch make it a good excipient?
ANS: Corn starch is used for two reasons, to be a binder and also a disintegrant. A disintegrant enables tablets to break down into smaller part so that the drug can be released for absorption. It also helps to bind all the other ingredients of the tablet together.⁴

REFERENCES

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